CHAPTER C.12
LCA BENEFITS ASSESSMENT PROTOCOLS

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12.1 Introduction

Investments in ecological restoration by the Corps are based upon evaluation of restoration outputs where those outputs reflect the effects of restoration measures on ecosystem value and productivity. ER 1005-2-100 calls for the use of metrics that assess increases in “ecosystem” value and productivity. While the most prominent indicator of ecosystem degradation in coastal Louisiana is the dramatic loss of wetland acreage in the late 20th century, the Benefits Protocols presented here have a broader purpose. These protocols can be used to evaluate the achievement of alternative plans in providing an array of ecosystem services of national significance – not simply the reversal of wetland loss.

These protocols have been developed to synthesize the wealth of ecosystem dynamics information being generated in the assessment of LCA alternatives. The information covers an array of ecosystem attributes and functions and the Benefits Protocols provide a means of comparing complex patterns, both in space and time, of ecosystem change. They have been formulated and developed by a multi-disciplinary team of agency experts and university scientists with extensive experience both of the Louisiana coastal ecosystem and of the use of ecosystem benefits measures in restoration planning and assessment.

Each protocol has been designed to contribute to the LCA decision-making process in different ways. Benefit Protocol #2 will be used as input to the Institute of Water Resources' Plan procedure as part of the incremental cost-effectiveness analysis to narrow down the number of alternatives to a Final Array for more detailed consideration. The other Benefits Protocols provide additional information on how alternative actions influence specific aspects of the ecosystem and will be used to inform LCA decision makers as they consider the Final Array and determine which best meets LCA goals and objectives. In all cases the Benefits Protocols are used to compare the effects of alternatives on the coastal ecosystem rather than to specifically project future conditions.

12.2 Ecosystem Objectives

The alternative formulation for the LCA study has been based on two Ecosystem Objectives and these have formed the basis for development of the Benefits Protocols described here.

Ecosystem Objective 1:

Increase land-water ratios, enhance connectivity and material exchanges to improve productivity and sustain diverse fish and wildlife habitats.

Ecosystem Objective 2:

Reduce nutrient delivery to the shelf by routing Mississippi River waters through estuarine basins.

12.3 Benefits Protocols

Table C.12-1 summarizes the role of each of the six Benefits Protocols developed to support LCA decision-making. Detailed descriptions of the rationale for each protocol and the specifics of the algorithms to be used are included in the following sections.

All benefits values will represent the net difference between the future with the alternative (FWA) and the no-action alternative, or the future without the alternative (FWO). This calculation is made for each protocol once benefits values for all alternatives, including no-action, are available.

Table C.12-1 Summary Description of LCA Benefits Protocols

Protocol	Aspect of Ecosystem Change	Essential inputs
B1	Productivity and Habitat use – Habitat Quality	Primary productivity of land and water Use of habitat by 12 coastal species
B2	Quantity of land, Quality of habitat, and Nitrogen removal	Acres of land Primary productivity of land and water Use of habitat by 12 coastal species Removal of N from Mississippi River water.
B3	Quantity of land	Acres of land
B4	Nitrogen removal	Removal of N from Mississippi River water
B5	Value of fish and wildlife habitat	Use of habitat by 12 coastal species
B6	Selected stakeholder interest issues	Various combinations of the assessment output (see detailed description below)

Note: The ordering of the protocols reflects the team development process and does not imply any order in which they will be applied or any priority ranking.

12.4 Spatial and Temporal Scales

Some of the inputs in Table C.12-1 are derived at a resolution of 1 km^2 across the coast. Thus, 1 km^2 is the smallest scale at which any of the protocols can be applied. Others are, by definition, values that describe the effect of the alternative at the subprovince scale (*e.g.*, acres of land). The vast array of information provided by the alternatives assessment process allows the individual Benefits Protocols to use input at many spatial scales across the coast. The detailed descriptions below include information on the way in which data from these various scales is combined. In all cases, the protocols seek to reflect the effect of the alternative on the entire subprovince.

While the models used to generate the output are applied at various time steps (Twilley *et al.* 2003), the desktop approach allows benefits to be calculated in annual increments. The Benefits Protocols that produce information in 'unit' form (*e.g.*, habitat units) can be accumulated at decadal intervals to provide information on benefits over 50 years or benefits over shorter intervals as average annual benefits.

12.5 Benefits Protocol #1 (B1)

B1 has been developed to reflect the relative progress made by alternatives in reaching Ecosystem Objective 1. It combines two components:

- Primary Productivity
- Habitat Use

Values for each component are derived, as described below, for each 1 km^2 cell and combined to produce a Habitat Suitability Index (HSI) that reflects Quality of Habitat (HSIQL). The HSIQLs of all cells within a subprovince are totaled to account for the area of the subprovince and produce Habitat Quality Units (HQUs).

Primary productivity in each 1 km^2 cell was designated as Habitat Suitability Productivity (HSP). This input was provided by the Habitat Switching desktop module (Visser *et al.* 2003a) for the wetland habitats and by the Water Quality desktop module (Rivera *et al.* 2003) for the open water areas. The desktop teams scaled inputs, *i.e.*, benefits input values will vary between 0 and 1, to show the relationship of the calculated primary productivity to an expected optimal value.

Habitat use in each cell was derived from the results of the Habitat Use desktop module (Foret *et al.* 2003). The HSIs for each of the12 animals modeled in the desktop was combined into three general groupings based on the salinities in the parts of the estuary that each animal uses the most.

- Lower salinity areas (Fr) – otter, mink, alligators, dabbling ducks, largemouth bass.
- Moderate salinity areas (Mod) – white shrimp, croaker, menhaden, muskrat.
- Higher salinity areas (Sal)– oyster, spotted seatrout, brown shrimp.

This grouping was necessary because the Habitat Use desktop module includes those animals for which HSI models from the USFWS Habitat Evaluation Procedures were already available or for which models could be readily developed in the time available. Thus the species included may not adequately reflect the array of life histories for species using the coastal ecosystem. The grouping minimized any bias in the net HSI that may result from the types of animals encompassed by the analysis. Habitat Suitability Indices for each animal were combined arithmetically within the appropriate group. This produced three group HSI values for each cell. These group HSIs were again combined arithmetically to give a net habitat use value for each cell.

Primary productivity HSPs and habitat use HSIs were combined geometrically to show HSIQL for each cell as in the following formula:

$$HSIQL = [HSP \times (HSI_{Fr} + HSI_{Mod} + HSI_{Sal})/3]^{½}$$

The values of HSIQL for each 1 km^2 cell were totaled for the subprovince to produce Habitat Quality Units (HQU). This benefit protocol, expressed as average annual HQUs (calculated from the individual values at year0, year 10, year 20, year 30, year 40 and year 50), reflect the pattern of changes in habitat quality over the fifty years of the no action and alternative projections.

12.6 Benefits Protocol #2 (B2)

This protocol was used to generate values for input to the IWR Plan. It is one comprehensive benefit number which will indicate the achievements of the alternative in meeting Ecosystem Objectives 1 and 2 and also will indicate the effectiveness in creating or preserving land.

The three components to be combined are:

- Quality of Habitat
- Quantity of Land
- Nitrogen Removal

Values for each component were derived, as described below, for each 1km^2 cell and combined to produce an Overall Suitability Index (OSI). The OSIs of all cells within a subprovince were totaled to produce Benefits Units (BUs) for the entire subprovince.

12.6.1 Quality of Habitat

Quality was designated as Habitat Suitability Quality (HSIQL). This was derived from two parameters, primary productivity and habitat use and derived as described for Benefits Protocol #1.

12.6.2 Quantity of Land

Quantity was designated as Suitability Index Quantity (SIQT). This is a measure of how much land the alternative creates/preserves in the subprovince and is derived from the results of the Land Building desktop module (Suhayda *et al.* 2003) and the Nourishment desktop module (Visser *et al.* 2003b). This value was derived using the ratio of the amount of land created/preserved by the alternative and the amount of land in the subprovince in 1932. The year 1932 was chosen because that was the first year that comprehensive aerial photograph coverage was available for nearly the entire Louisiana coast allowing an accurate assessment of land-water. It was also very close to the time when major human alteration of the coast began, ultimately resulting in the collapse of the coastal ecosystem.

The ratio was derived using land areas for the entire subprovince. The *same* SIQT value was applied to all 1 km^2 cells within the subprovince:

$$SIQT = L_{alt}/L_{32}$$

Note that this value in a cell reflects the effect of the alternative on the entire subprovince – not the specific land loss/gain within the cell. SIQT was not allowed to exceed 1, even if the land created/preserved is greater than the amount of land in 1932.

12.6.3 Nitrogen removal

This was designated as Suitability Index Nitrogen (SIN). This was measured using the amount of nitrogen removed by the alternative in tons per year provided by the Water Quality desktop module. Approximately 1.6 million metric tons of nitrogen are carried by the Mississippi River to the Gulf of Mexico each year, causing the development of an extensive hypoxic zone on the Louisiana shelf (CENR 2000). Mitsch *et al.* (2001) estimated that approximately six percent of this or 100,000 tons per year could be removed by diversions of the Mississippi River into Louisiana wetlands. The amount removed by the alternative (N_{alt}) was scaled by this estimate of potential removal (N_6) using the following formula:

$$SIN = N_{alt}/N_6$$

If N_{alt} exceeded 100,000 tons/year then the value of SIN was one. SIN was derived using values for the entire subprovince and the *same* value for SIN was applied to all 1 km^2 cells.

12.6.4 Calculating B2

The Overall Suitability Index (OSI) for each cell combines HSIQL, SIQT and SIN. In the professional judgment of the Benefits Protocols Work Group, the components that assess the changes within the estuaries (HSIQL and SIQT) should be weighted as four times as important as SIN. Ecosystem Objective #1 is considered the most important in an area that is losing 24 square miles per year. Ecosystem Objective #2 is an integral part of the LCA approach for subprovinces 1, 2 and 3. However, the weighting reflects the numerous other ways in which nutrient delivery to the shelf could be reduced other than by directing flows through Louisiana estuaries. In addition SIN was combined arithmetically to ensure that the two objectives separately provide benefit to the coastal ecosystem. Success in achieving Ecosystem Objective #2 was not assessed in subprovince 4 as the Chenier Plain has no direct riverine connection to the Mississippi. Consequently, the OSI calculation was applied without SIN in subprovince 4:

The OSI was calculated for each cell according to the following formula:

$$OSI = \{[4 \times (HSIQL \times SIQT)^{1/2}] + SIN\}/5 \qquad \text{Subprovinces 1, 2 and 3}$$

$$OSI = (HSIQL \times SIQT)^{1/2} \qquad \text{Subprovince 4}$$

Benefits Units (BUs) were calculated for the entire subprovince by totaling the OSIs of all cells. This accounted for the area within the subprovince. In addition, this benefit protocol was expressed as average annual BUs (calculated from the individual values at year 0, year 10, year 20, year 30, year 40, and year 50) to reflect the pattern of changes in ecosystem attributes over the full fifty years of the no action and alternative projections.

12.7 Benefits Protocol #3 (B3)

This benefit measured the achievement of the alternative in creating and preserving land within the subprovince. B3 consisted of the amount of land produced by the alternative after 50 years, and was expressed in acres relative to no-action. Land includes fresh, intermediate, brackish and saline marshes, swamp, wetland forest, wetland shrub/scrub, and barrier islands, but does not include fastlands.

12.8 Benefits Protocol #4 (B4)

The achievement of the alternatives in meeting Ecosystem Objective 2 was assessed using the amount of nitrogen removed by the alternative in tons per year, as provided by the Water Quality desktop module. To put this in the context of overall plans for nutrient reduction in the Mississippi River, this value was presented relative to the Action Plan goal developed by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force that was presented to Congress in January 2001. The action plan called for a 30% reduction in nitrogen loading. The mean annual load of total nitrogen delivered to the Gulf is 1.6 million metric tons (CENR 2000). A 30 percent reduction of this would be 480,000 metric tons annually.

Thus B4 was expressed as nutrient removal percent (NR%):

$$NR\% = [N_{alt}/ 480{,}000] \times 100$$

and represents the percentage of the Action Plan goal achieved by the alternative on an annual basis.

12.9 Benefits Protocol #5 (B5)

This Benefits Protocol was developed to estimate the effects of various restoration alternatives on various fish and wildlife habitats within the coastal zone. Four habitat types were selected which represent the major habitat types found within the Louisiana coastal zone. Those four habitat types were fresh/intermediate marsh, brackish marsh, saline marsh, and swamp. The Habitat Use desktop module provided an HSI for each species (listed in Table C.12 -2) for each 1km^2 cell.

Table C.12-2 Species Included in Benefit and Variable Designations

V1 White shrimp	V7 Largemouth bass
V2 Brown shrimp	V8 American alligator
V3 Oyster	V9 Muskrat
V4 Gulf menhaden	V10 Mink
V5 Spotted seatrout	V11 Otter
V6 Atlantic croaker	V12 Dabbling ducks

The HSI values for each species were averaged across all 1 km^2 cells for each habitat type. The averaged HSI values were combined in a habitat-specific HSI formula to determine fish and wildlife habitat quality for each of the four habitat types. The mean HSI values for each species were combined as follows:

HSI Calculation for Fresh/Intermediate Marsh:

$$\frac{1.5V_1 + 1.5V_4 + 1.5V_6 + 2.8V_7 + 2.8V_8 + V_9 + 1.2V_{10} + 1.2V_{11} + 3.2V_{12}}{16.7}$$

HSI Calculation for Brackish Marsh:

$$\frac{2.5V_1 + 2.5V_4 + 2.5V_6 + 1.2V_3 + 1.5V_5 + 1.5V_2 + 0.7V_8 + 1.2V_9 + V_{10} + V_{11} + 1.2V_{12}}{16.8}$$

HSI Calculation for Saline Marsh:

$$\frac{1.5V_1 + 1.5V_4 + 1.8V_6 + 2.5V_3 + 3.2V_5 + 3.2V_2 + V_9 + 0.7V_{10} + 0.7V_{11} + 0.7V_{12}}{16.8}$$

HSI Calculation for Swamp:

$$\frac{V_8 + V_{10} + V_{11} + V_{12}}{4}$$

At this time, model output does not provide a salinity classification for open water cells. Model output does not distinguish between fresh/intermediate open water, brackish open water or saline open water. All 1 km^2 open water cells, regardless of salinity zone, are simply classified as open water. Therefore, it cannot be specified (*i.e.*, via computer code) which habitat-specific HSI formula to apply to those cells to obtain a measure of fish and wildlife habitat quality. However, model output provides an estimate of the open water acreage within each salinity zone, which allows the application of a habitat-specific HSI formula to those acreages. Therefore, a standardized HSI value was calculated for the open water cells within each salinity zone using the HSI formulas above.

Within each HSI formula, each species' HSI value is weighted based on its relative importance in determining habitat quality for that particular habitat type. For instance, in the fresh/intermediate HSI formula, brown shrimp, oyster, and spotted seatrout are not included (*i.e.*, weighted with a zero) because they are not important in determining habitat quality in that zone. The relative importance of each species was determined by best professional judgment and/or expert opinion and follows procedures used by the U.S. Fish and Wildlife Service in developing species-specific HSI models (U.S. Fish and Wildlife Service 1980). The species weightings are shown in Table C.12-3.

An HSI was calculated for each target year (*e.g.*, TY0, 10, 20, 50) and then multiplied by the habitat type acreage to get habitat units (HU) as follows:

HU Fresh Marsh = Combined HSI of fresh/intermediate species X acres of fresh/intermediate marsh

HU Brackish Marsh = Combined HSI of brackish species X acres of brackish marsh

HU Saline Marsh = Combined HSI of saline species X acres of saline marsh

HU Swamp = Combined HSI of swamp species X acres of swamp

For each habitat type, the HUs were summed and the HUs for each habitat type was totaled to provide **Subprovince HUs** for each subprovince:

Subprovince HUs = HUs Fresh Marsh + HUs Brackish Marsh + HUs Saline Marsh + HUs Swamp

This took into account the areas covered by each habitat type within the subprovince. In addition, this benefit protocol was expressed as average annual HUs (calculated from the individual values at year 0, year 10, year 20, year 30, year 40 and year 50) to reflect the pattern of changes in fish and wildlife habitat over the full fifty years of the no action and alternative projections.

Table C.12-3 Variable Weights (%) for Each Model

Species	Fresh / Intermediate Marsh	Brackish Marsh	Saline Marsh	Swamp
White Shrimp	9	15	9	
Gulf Menhaden	9	15	9	
Atlantic Croaker	9	15	11	
Oyster		7	15	
Spotted Seatrout		9	19	
Brown Shrimp		9	19	
Largemouth Bass	17			
American Alligator	17	4		25
Muskrat	6	7	6	
Mink	7	6	4	25
Otter	7	6	4	25
Dabbling Ducks	19	7	4	25
Total	100	100	100	100

12.10 Benefits Protocol #6 (B6)

The measures included in Benefits Protocol #6 reflect aspects of ecosystem change that are of specific interest to stakeholders or resource agencies. The measures included here will likely change as the decision-making process proceeds and issues arise for which information regarding alternative performance is required. It is anticipated that the following values, explained below, will be generated.

12.10.1 Individual Species and Species Groupings

For each of the following species or groupings, output from the Habitat Use desktop module provides HSI values at the 1 km^2 scale. These were combined as shown in Table C.12-4 to produce grouped HSI values for each cell, and the HSI values for all cells in a subprovince were totaled to produce 'units' reflecting the value and size of the subprovince. The variables for each species are as shown in Table C.12-2.

Table C.12-4 Species Grouping used in Benefits Protocol #6

Species/grouping	Species included	Calculation	Benefit Designation
Lower salinities group (as in B1)	Otter, mink, American alligators, dabbling ducks, largemouth bass	$\frac{(V11+V10+V8+V12+V7)}{5}$	Low units
Moderate salinities group (as in B1)	White shrimp, Atlantic croakers, gulf menhaden, muskrats	$\frac{(V1+V6+V4+V9)}{4}$	Moderate units
Higher salinities group (as in B1)	Oyster, spotted sea trout, brown shrimp	$\frac{(V3+V5+V2)}{3}$	High units
Commercial harvest species group	Brown and white shrimp, oysters, gulf menhaden, American alligators	$\frac{(V1+V2+V3+V4+V8)}{5}$	Commercial units
Recreational harvest species group	Largemouth bass, dabbling ducks, spotted sea trout	$\frac{(V7+V12+V5)}{3}$	Recreational units
Oyster habitat	Oysters	V3	Oyster units

12.10.2 Habitat Types

The LCA emphasis on the ecosystem as a whole rather than a specific assemblage of wetland types is reflected in the previously described benefits, many of which combine multiple ecosystem attributes, including wetland type, to show the various effects of alternatives. However, the amount of each wetland type resulting from the alternatives is useful information for decision making. Thus the following information was generated for each subprovince for each alternative and designated as follows:

- Acreage of forested wetlands – forest acres
- Acreage of fresh marsh – fresh acres
- Acreage of intermediate marsh – intermediate acres
- Acreage of brackish marsh – brackish acres
- Acreage of salt marsh – salt acres.

12.11 Limitations

The development of the Benefits Protocols (Table C.12-5) described here has been a cooperative effort among the team and has benefited from interaction with many other members of the Project Delivery Team. While the Work Group believes the protocols represent the best approach for evaluating the success of alternatives in achieving LCA ecosystem objectives for the current planning process, the Group acknowledges several specific shortcomings and some limitations that are likely inevitable in the early stages of planning such a complex ecosystem restoration effort. The Work Group is optimistic that more detailed planning processes occurring in the PIR phase will be able to use these efforts as a foundation for evaluating project alternatives within the ecosystem context.

Table C.12-5 Summary of Benefits Protocol Calculations

Protocol #	Aspect of Ecosystem Change	Calculations
B1	Productivity and Habitat use – Habitat Quality	HSIQL = $[HSP \times (HSI_{Fr} + HSI_{Mod} + HSI_{Sal})/3]^{½}$
B2	Quantity of land, Quality of habitat, and Nitrogen removal	SIQT = L_{alt}/L_{32} SIN = N_{alt}/N_6 OSI = $\{[4 \times (HSIQL \times SIQT)^{½}] + SIN\}/5$ Sub 1,2,3 OSI = $(HSIQL \times SIQT)^{½}$ Sub 4
B3	Quantity of land	Acres of land
B4	Nitrogen removal	NR% = [Nalt/ 480,000] x 100
B5	Value of fish and wildlife habitat	HV = ΣHU for each habitat type
B6		
B6 - low	Lower salinities species group	$\frac{(V11+ V10 + V8+ V12+ V7)}{5}$
B6 - mod	Moderate salinities species group	$\frac{(V1 + V6 + V4 + V9)}{4}$
B6 - high	Higher salinities species group	$\frac{(V3 + V5 + V2)}{3}$
B6 - com	Commercial harvest species group	$\frac{(V1 + V2 + V3 + V4 + V8)}{5}$
B6 - rec	Recreational harvest species group	$\frac{(V7 + V12 + V5)}{3}$
B6 - oyst	Oysters	V3
B6 - forest	Acreage of forested wetlands	Forest acres
B6 –fresh	Acreage of fresh marsh	Fresh acres
B6 – inter.	Acreage of intermediate marsh	Intermediate acres
B6 – brack	Acreage of brackish marsh	Brackish acres
B6 - salt	Acreage of salt marsh	Salt acres

The Work Group developed these protocols around the concepts encompassed by the two LCA Ecosystem Objectives. While most elements of these objectives (*i.e.*, productivity, sustainable fish and wildlife habitat, nutrient removal) are included within one or more of the Benefits Protocols, the Work Group recognized that the issue of diversity is not specifically addressed. Attempts were made to identify data on species diversity in the Louisiana coastal ecosystem but no existing databases were adequate to reflect species diversity across the study area. While the concept of 'richness' may have been addressed by considering habitats rather than species, few alternatives altered the number of habitats represented in the study area.

Consequently, a metric reflecting habitat diversity would not be useful in distinguishing among alternatives. As the alternatives alter the acreage of habitats within subprovinces, the Work Group considered the use of a metric reflecting ‘evenness’ of habitats. However, unlike other ecosystem restoration projects, the LCA does not seek to restore some ideal or historic landscape condition. Without a reference condition against which evenness of habitat distribution could be assessed, this aspect of diversity could not be incorporated into the current assessment. Many consider biodiversity one of the most inclusive indicators of ecosystem outputs (Stakhiv et al, 2003) and the Work Group recommends that efforts to improve the consideration of biodiversity in future LCA planning be initiated immediately.

There are many aspects of Louisiana coastal ecosystem structure and function that are not encompassed by the protocols presented here. The Work Group recognized that concepts such as habitat connectivity are potentially important influences on ecosystem function but the generalized nature of the modeling and assessment effort did not allow consideration of such spatially specific ecosystem attributes. Similarly, specific habitats which are scarce, such as maritime forest, or which are more ephemeral, such as submerged aquatic vegetation, could not be encompassed by this effort because of the time and space scales at which information from the models is provided. This does not diminish their importance to the ecosystem or discount their consideration in the decision-making process. It merely, points to the limitations of the current approach in encompassing the array of Louisiana coastal ecosystem attributes and points to the need for the development of assessment tools that can be more inclusive.

The use of the Benefits Protocols in the LCA planning process builds upon the efforts of other LCA workgroups which have worked in parallel to develop numerical and desktop modeling approaches. Figure C.12-1 shows the relationship between the Benefits Protocols Work Group and these workgroups. Essentially, the Benefits Protocols Work Group relies on the output from the numerical and desktop efforts to provide input variables to any benefit assessment tools. Accordingly, the use of the tools developed by this Work Group and the approach recommended here are potentially limited by the unforeseen challenges posed to those groups.

The reports of the Desktop and Numerical modeling teams all point to the many assumptions and generalizations that have been made in the development of their recommended algorithms. These will not be repeated here but it is clear that some of the estimates those teams will develop for use in the benefits assessment will be more accurate than others. Time has not allowed this LCA effort to specifically assess the errors associated with each analysis, or how they propagate and are combined through the complex data sharing and integration effort that precedes the benefits assessment in Figure C.2.1. Such analysis should be conducted as part of the expected development and refinement of LCA evaluation methods.

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